Definition of venous reflux in lower-extremity veins

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Purpose: **This prospective study was designed to determine the upper limits of normal for duration and maximum velocity of retrograde flow (RF) in lower extremity veins.**

Methods: **Eighty limbs in 40 healthy subjects and 60 limbs in 45 patients with chronic venous disease were examined with duplex scanning in the standing and supine positions. Each limb was assessed for reflux at 16 venous sites, including the common femoral, deep femoral, and proximal and distal femoral veins; proximal and distal popliteal veins; gastrocnemial vein; anterior and posterior tibial veins; peroneal vein; greater saphenous vein, at the saphenofemoral junction, thigh, upper calf, and lower calf; and lesser saphenous vein, at the saphenopopliteal junction and mid-calf. Perforator veins along the course of these veins were also assessed. In the healthy volunteers, 1553 vein segments were assessed, including 480 superficial vein segments, 800 deep vein segments, and 273 perforator vein segments; and in the patients, 1272 vein segments were assessed, including 360 superficial vein segments, 600 deep vein segments, and 312 perforator vein segments. Detection and measurement of reflux were performed at duplex scanning. Standard pneumatic cuff compression pressure was used to elicit reflux. Duration of RF and peak vein velocity were measured immediately after release of compression.**

Results: **Duration of RF in the superficial veins ranged from 0 to 2400 ms (mean, 210 ms), and was less than 500 ms in 96.7% of these veins. In the perforator veins, regardless of location, outward flow ranged from 0 to 760 ms (mean, 170 ms), and was less than 350 ms in 97% of these veins. In the deep veins, RF ranged from 0 to 2600 ms. Mean RF in the deep femoral veins and calf veins was 190 ms, and was less than 500 ms in 97.6% of these veins. In the femoropopliteal veins, mean RF was 390 ms, and ranged from 510 to 2600 ms in 21 of 400 segments; however, RF was less than 990 ms in 99% of these veins. Duration of RF was significantly longer in all three veins systems in patients ($P < .0001$ for all comparisons). With a cutoff value of more than 1000 ms rather than more than 500 ms, prevalence of abnormal RF in the femoropopliteal veins was significantly reduced, from 29% to 18% ($P = .002$). Thirty-seven vein segments (2.4%) had RF greater than 500 ms in the supine position, compared with less than 500 ms in 22 of these vein segments (59%) in the standing position. Of the 48 vein segments (3.1%) with RF greater than 500 ms in the standing position, RF was less than 500 ms in 6 of these vein segments (13%) in the supine position. Similar observations were noted in patient veins. There was no association between RF and peak vein velocity. Peak vein velocity had no significance in determining reflux.**

Conclusions: **The cutoff value for reflux in the superficial and deep calf veins is greater than 500 ms. However, the reflux cutoff value for the femoropopliteal veins should be greater than 1000 ms. Outward flow in the perforating veins should be considered abnormal at greater than 350 ms. Reflux testing should be performed with the patient standing. (J Vasc Surg 2003;38:793-8.)**

Retrograde flow (RF) in the lower-extremity veins occurs physiologically just before valve closure, and pathologically as a result of valve absence or incompetence from recanalization, dilatation, or denervation.[1] Attempts have been made to define abnormal duration of RF. Cutoff values of greater than 0.5 seconds or greater than 1.0 second have been proposed.[1-4] These studies have had small sample size and assessed few sites in the lower-limb veins. It is therefore unknown whether duration of RF should be the same in superficial and deep veins. In addition, no work has been done to define perforator vein reflux. Controversy exists about these veins, because they may exhibit inward and outward flow. In a recent study, incompetent perforating veins had a net flow toward the superficial veins.[5] However, even in that study a cutoff value for reflux was not determined. Therefore the present study was performed to determine the upper limits of normal for duration and maximum velocity of RF in lower-extremity veins.

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Competition of interest: none.

Presented at the Fourteenth Annual Meeting of the American Venous Forum, La Jolla, Calif, Feb 21-24, 2002.

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0741-5214/2003/$30.00 + 0

doi:10.1016/S0741-5214(03)00424-5

PATIENTS AND METHODS

In this prospective study 80 limbs of 40 healthy subjects and 60 limbs of 45 patients with chronic venous disease (CVD) were evaluated with duplex scanning for venous reflux. Volunteers had no signs or symptoms of CVD and no known previous episode of superficial or deep vein thrombosis. Volunteers, who were medical students, friends, colleagues, and support staff, included 20 men and 20 women, with mean (± SD) age of 30 ± 7 years (range, 31-54 years; median, 25 years; interquartile range [IQR], 24, 39). Although we did not try to select the subjects, none were obese or had any significant disease. Patients, who were referred to the vascular laboratory from our venous clinic, included 29 women and 16 men, with mean age of 48 ± 11 years (range, 22-73 years; median, 46 years; IQR 38, 59). Three patients had class 1 CVD, 18 patients had class 2 CVD, 8 patients had class 3 CVD, 9 patients had class 4 CVD, 3 patients had class 5 CVD, and 4 patients had class 6 CVD. Thirty-seven patients (82%) had symptomatic CVD. These patients were consecutive, but 8 limbs in 5 other patients were excluded because they had undergone previous venous surgery.

Each limb was examined for reflux at 16 venous sites, including the common femoral, deep femoral, and proximal and distal femoral veins; proximal and distal popliteal veins; gastrocnemial vein; anterior and posterior tibial veins; peroneal vein; greater saphenous vein, at the saphenofemoral junction, thigh, upper calf, and lower calf; and lesser saphenous vein, at the saphenopopliteal junction and mid-calf. The main calf veins were examined in the mid-calf. In the paired calf veins it was often observed that in areas with interconnections where a communicating vein connects a pair of veins the RF was much longer. These segments were not included in the analysis, and an adjacent segment was tested instead. Paired veins were screened, and only the one with the longer RF was included in the analysis. The gastrocnemial veins were evaluated 2 cm below their union with the popliteal vein. These veins further down in the muscle belly usually become larger and have very slow flow. At that location it is not easy to elicit a good response; therefore this area was avoided. Duration of outward flow, ie, flow toward the superficial veins, in the perforator veins along the course of the assessed veins was also evaluated. Detection and measurement of reflux was performed with duplex scanning with an ATL HDI 3000 color- flow duplex scanner (Advanced Technology Laboratories, Bothel, Wash) with a variable frequency 4 to 7 MHz linear array transducer. One author (N.L.) performed the duplex scanning and read the scans. Black-and-white pictures were taken, and videotapes were made.

Rapid-inflation pneumatic cuffs (Aircast, Summit NJ) with maximum pressure of 80 mm Hg were used to augment flow. These were placed distal to the venous segment under investigation. The same pressure (80 mm Hg) was used with subjects both standing and supine. Time to inflation was 0.3 seconds, inflation was maintained for 1 second, and deflation was achieved in less than 1 second. For groin and proximal thigh vein measurements the cuff was placed on the lower thigh, and for the other veins it was placed on the lower calf.

Duration of RF and peak vein velocity were measured immediately after release of compression. Peak RF velocity and duration of RF were recorded in all volunteers in both the standing and supine positions. Because of the long duration of the test, only 10 patients were examined in both positions; the remainder were examined only in the standing position.

Table I. Prevalence of prolonged retrograde flow in superficial veins (standing position)

	Duration of retrograde flow			
	<500 ms		*>500 ms*	
Vein segment	*n*	*%*	*n*	*%*
SFJ	79	98.8	1	1.2
GSV, thigh	78	97.5	2	2.5
GSV, upper calf	77	96.2	3	3.8
GSV, lower calf	73	91.2	7	8.8
SPJ	79	98.8	1	1.2
LSV	78	97.5	2	2.5
	464/480	96.7	16/480	3.3

SFJ, Saphenofemoral junction; *GSV*, greater saphenous vein; *SPJ*, saphenopopliteal junction; *LSV*, lesser saphenous vein.

We have observed that some patients with significant pitting edema and dilated veins do not demonstrate reflux with manual or automated rapid compression. In these patients RF is determined during active dorsiflexion or plantar flexion.

Collective data from each venous segment were analyzed individually from both positions, and a definition of abnormal RF was calculated at the best separation point and in comparison with the data from patients. Statistical analysis of the data was performed with descriptive statistics and the χ^2 test, with 95%, 99% confidence intervals (CI). Distribution of continuous data was abnormal; therefore median and IQR values are also given. Statistical significance was determined with the Mann-Whitney test. Unless otherwise indicated, data were obtained with the subjects in the standing position.

RESULTS

In the superficial veins 480 segments were evaluated. Mean duration of retrograde flow was 210 ms (range, 0-2400 ms; 95% CI, 206-214). In 16 vein segments (3.3%) RF was greater than 500 ms. Duration of RF is shown in Table I. Reflux was more common in calf vein segments, but the difference was not significant (P = .09). Reflux was more frequent in the greater saphenous vein compared with the lesser saphenous vein, without reaching significance (P = .32). In the patients 360 vein segments were assessed. RF greater than 500 ms was detected in 202 segments (56%; P < .0001 compared with control values). This does not include other segments of the main saphenous veins, tributary vessels, and nonsaphenous superficial veins. If these veins were included, prevalence of reflux in the superficial veins overall would have been 93% (56 of 60 limbs). In varicose vein segments RF was always greater than 500 ms. However, of 202 segments with RF greater than 500 ms, 114 segments (56%) were dilated but had no varicosities and 18 segments (9%) had normal diameter or were less than 2.5 mm in diameter.

Of 273 perforator veins detected, 214 were below the knee and 59 were in the thigh. Outward flow in the perforating veins, regardless of location, ranged from 0 to

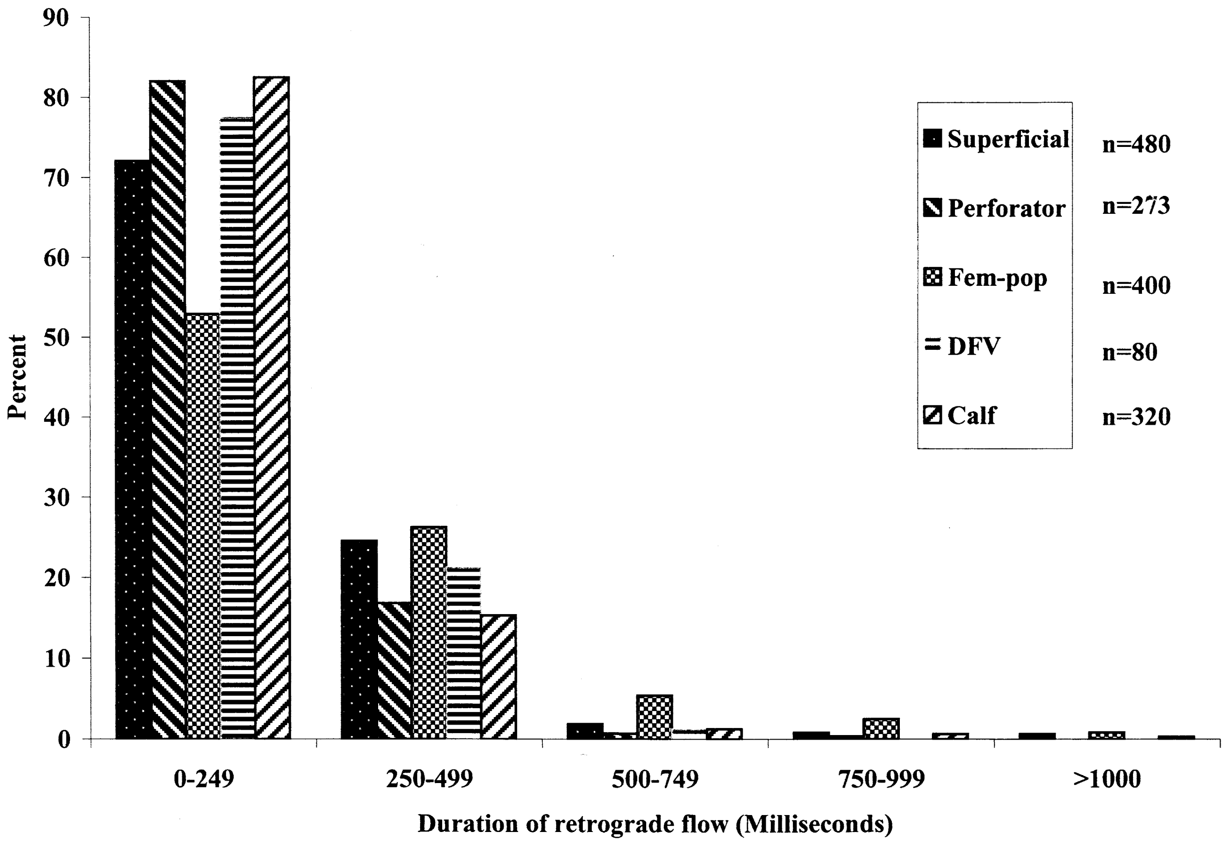

Fig 1. Duration of retrograde flow in all vein segments in healthy volunteers during standing.

760 ms (mean, 170 ms). Only 3 perforator veins (1%) in the calf and none in the thigh had RF greater than 500 ms. Indeed, 97% of these veins had RF less than 350 ms. RF duration in the calf was much longer than in the thigh (mean, 180 ms [95% CI, 176-184] vs 150 ms [95% CI, 145-155]; $P < .0001$). Incompetent perforator veins in all 3 cases were associated with superficial RF greater than 1200 ms. Of 312 perforator veins identified in patients, 71 veins had RF greater than 500 ms ($P < .0001$ compared with healthy volunteers). If the cutoff for normal was set at 350 ms, 82 perforator veins would have had abnormal RF.

In the deep veins 800 segments were examined: 320 in the thigh, 240 in the popliteal fossa, and 240 in the calf. In these veins RF ranged from 0 to 2600 ms. RF duration for all veins is shown in Fig 1. Mean RF value in the deep femoral and calf veins was 190 ms (95% CI, 188-192). In 97.6% of these veins RF was less than 500 ms; only 1 deep femoral vein (1.2%) and only 7 calf veins (2.2%) had RF greater than 500 ms. In the femoropopliteal veins, mean RF was 280 ms (95% CI, 375-385), significantly longer than in superficial, perforator, deep femoral, and calf veins ($P < .0001$ for all comparisons). In 21 of 400 segments RF ranged from 510 to 2600 ms; however, in 99% of these veins RF was less than 990 ms. With 1000 ms as the cutoff for abnormal RF, only 4 of 400 segments (1%) would have reflux. Of 600 segments examined in patients, 152 had RF greater than 500 ms ($P < .0001$ compared with control values). In the femoropopliteal veins the prevalence of RF greater than 500 ms was 29% (87 of 300 veins; $P < .0001$ compared with control values). With the cutoff value at 1000 ms, prevalence of abnormal RF was significantly reduced, at 18% (54 of 300 veins; $P = .002$).

Median and IQR for all vein systems assessed in healthy volunteers and patients are illustrated in Fig 2. In all comparisons, patients had significantly longer RF than did volunteers ($P < .0001$). Depending on degree of overlap between values for healthy volunteers and patients, 95% to 99% of RF values were used to determine the best cutoff points for normality. For superficial, deep calf, and deep femoral veins, abnormal RF was greater than 500 ms; for perforator veins abnormal RF was greater than 350 ms; and for femoropopliteal veins RF was greater than 1000 ms. These cutoff points would include 96.7%, 97.6%, 98%, and 99%, respectively, of normal segments in each group.

In 37 segments (2.4%) RF was greater than 500 ms in the supine position. RF duration was less than 500 ms in 22 of the 37 segments (59%) in the standing position. Location and positional changes in RF are shown in Table II. Of the 48 vein segments with RF greater than 500 ms in the standing position, RF was less than 500 ms in 6 segments

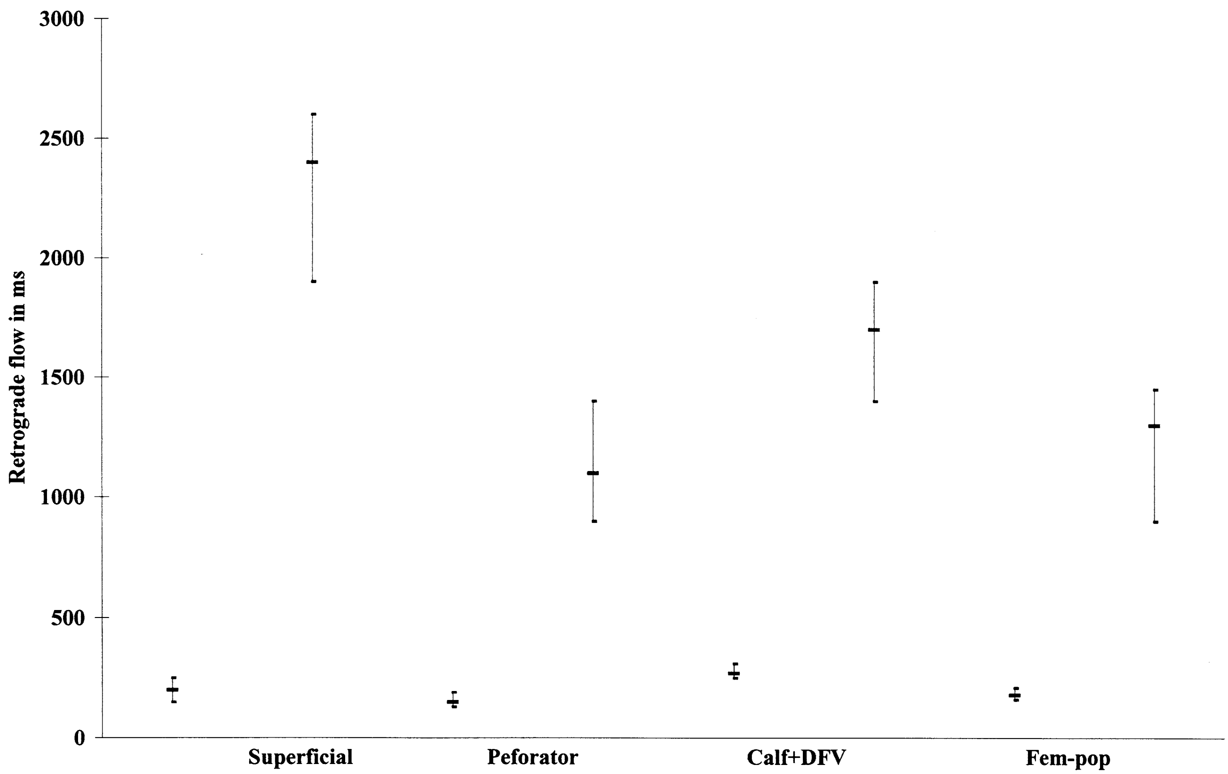

Fig 2. Median and interquartile range for retrograde flow in healthy volunteers and patients during standing. Retrograde flow was significantly longer in patients compared with volunteers in all veins (P < .0001 for all comparisons).

(13%) in the supine position. Similar observations were noted in the 10 patients in whom the test was done in both positions. In 59 segments RF was greater than 500 ms in the supine position; in the standing position, 8 of these segments (12%) had RF less than 500 ms. Of the 72 segments with RF greater than 500 ms in the standing position, 5 segments (7%) had RF less than 500 ms in the supine position.

Peak RF velocity varied from 8 to 35 cm/s in control subjects and from 9 to 83 cm/s in patients. Segments with RF greater than 500 ms had higher peak velocity (mean, 23.5 cm/s;, 95% CI, 20.2-26.8) compared with segments with RF less than 500 ms (mean, 15 cm/s; 95% CI, 14.8-15.2; P < .0001). Similar observations were noted in patients (RF >500 ms; mean, 41 cm/s; 95% CI, 36-48.5 vs RF <500 ms; mean, 18 cm/s; 95% CI, 14.5-24.2; P < .0001). Peak vein velocity of RF greater than 500 ms was significantly higher in patients than in control subjects. RF duration and peak RF velocity varied greatly. Also, because abnormal RF occurred at both low and high peak velocity, it was not possible to determine cutoff velocity values.

In 13 vein segments (3 greater saphenous vein, 1 lesser saphenous vein, 1 femoral vein, 1 popliteal vein, 2 gastrocnemial veins, 1 peroneal vein, 4 perforator veins) in 4 patients with significant pitting edema, RF was normal. RF became abnormal only during active dorsiflexion or plantar flexion.

Table II. Duration of retrograde flow from supine to standing position

	Duration of retrograde flow	
Vein segment	*Supine, >500 ms*	*Standing, <500 ms*
SFJ	1	1
Thigh	3	2
GSV, upper calf	5	3
GSV, lower calf	10	5
SPJ	0	0
LSV	3	2
Perforator	2	1
Femoropopliteal	7	4
Deep femoral	0	0
Calf	6	4
Total	37	22

SFJ, Saphenofemoral junction; *GSV*, greater saphenous vein; *SPJ*, saphenopopliteal junction; *LSV*, lesser saphenous vein.

DISCUSSION

Results of this study contribute to more accurate definition of reflux in the lower extremity. This is the only study that evaluated most veins in the lower extremity, with the largest sample size. In the superficial veins and deep femoral and deep calf veins, 96.7% and 97.6%, respectively, of segments tested had RF less than 500 ms, and in the perforator system 97% of 273 veins had outward flow less than 350 ms. These results confirm that the standard RF value of less than 500 ms applies to most superficial and deep veins, with the exception of the femoropopliteal veins.[1,3,4] In 99% of femoropopliteal veins, we found RF of less than 990 ms. These findings suggest that the cutoff value for reflux in the femoropopliteal segment should be increased to greater than 1000 ms for adequate specificity. More important, in the deep veins in patients a significant reduction in abnormal RF was seen, from 18% to 11%. In the perforating veins the cutoff value used thus far in most reports is 500 ms. This value has been used arbitrarily, and no study has been performed to determine a cutoff point. According to our data, this value can be safely lowered to 350 ms.

Duration of RF in the various normal veins varies, probably related to their size, valve location and number, tributary vessels uniting these veins, and wall compliance. The femoropopliteal veins are the largest veins in the extremity, and it may take longer for the valves to close, compared with valves in the superficial, perforating, and deep calf veins. The number of the valves in femoropopliteal veins is much fewer than in the deep calf veins, although the length of these vessels is comparable. Length may also be important, and could probably explain why the deep femoral vein, which is an equally large vessel but much shorter than the femoropopliteal veins, has shorter RF duration. No work has been done on these factors related to RF, and therefore these are only possible explanations and remain to be proved.

Twenty-two of 37 vein segments with reflux in the supine position were normal in the standing position. Of 38 vein segments with RF greater than 500 ms in the standing position, RF was less than 500 ms in 6 segments (13%) in the supine position. These findings indicate both increased specificity and sensitivity for detecting pathologic reflux in the standing position. Standing provides increased hydrostatic pressure, and the diameter of all veins in the lower extremity is larger. This contributes to longer RF in diseased vein segments. Standing allows more definitive closure of competent valves and offers more challenge to incompetent valves. Signs and symptoms of chronic venous insufficiency are improved or seen only in the standing position. It has been suggested that there should be a longer cutoff value (>2 s) for veins tested in the supine position.[6] However, because of our findings and reasons given above, we believe, like others, that valve competency should be tested only in the standing position when possible. The only other study that examined reflux in supine and standing positions, which was smaller and less definitive than the current study, supports our findings.[7]

There was no association between RF duration and peak vein velocity. This is in agreement with the findings of a previous study.[8] There are a few explanations for this, related to vein diameter and size of the capacitor into which the incompetent vein empties.

For example, when a large incompetent vein empties into a small capacitor, peak vein velocity is high but duration is short. When the refluxing vein is small and the capacitor is large, velocity is low and RF duration is long. Usually prolonged RF with high velocity is seen when the incompetent vein is dilated and the capacitor is large. Although these are consistent observations, we have not studied this systematically, and no definite conclusion can be made.

In 13 vein segments in four patients, reflux was induced only by active dorsiflexion or plantar flexion. It is possible that the pressure provided with the pump was highly attenuated by edema. This is also observed during manual compression. Active dorsiflexion or plantar flexion offers the highest pressure in the deep veins, because pressure is applied directly by the contracting muscles; thus emptying of the deep and muscular veins is most effective. Active flexion should be used in patients with edema and dilated veins when there is suspicion of reflux, but only after negative manual or automated calf compression.

As shown by other groups, duplex scanning is the best method for evaluating venous reflux.[1,9,10] In two separate studies, duplex scanning proved superior to descending phlebography.[11,12] As indicated in previous studies, pneumatic cuff compression provided consistently reproducible results and should be considered standard in determining lower extremity reflux.[1,13,14] Manual compression accurately elicits reflux, compared with pneumatic compression.[3] However, for studies like ours or for studies in which parameters of reflux are measured, use of pneumatic compression is imperative. The constant pressure of the pneumatic cuff provides a reliable and reproducible standard for such measurements.

Reflux can occur in any vein segment, irrespective of disease stage.[15] This is supported by our study, which included patients without signs and symptoms of chronic venous insufficiency. Also, saphenofemoral and saphenopopliteal reflux was uncommon. Previous studies have reported saphenous reflux without junctional involvement, even in patients with advanced disease.[16,17] Such data provide evidence for local development of reflux at "susceptible sites," which may be present in more than one location. Abnormal outward flow in the perforator veins was rare, and was found only in the presence of superficial vein reflux connecting with the incompetent perforator vein. This has been shown in other studies, indicating that perforator reflux is found together with deep and most often superficial vein reflux.[5,18]

CONCLUSIONS

Duplex scanning is the best method for evaluating reflux in individual vein segments. The cutoff value for reflux in the superficial veins, deep femoral veins, and deep calf veins is greater than 500 ms. However, the reflux cutoff value for the femoropopliteal veins should be greater than 1000 ms. Outward flow in the perforating veins should be considered abnormal at greater than 350 ms. Reflux testing in patients in the supine position should be avoided, and should be performed only in standing patients.

REFERENCES

1. van Bemmelen PS, Bedford G, Beach K, Strandness DE. Quantitative segmental evaluation of venous valvular reflux with duplex ultrasound scanning. J Vasc Surg 1989;10:425-31.
2. Araki CT, Back TL, Padberg FT, Thompson PN, Duran WN, Hobson RW. Refinement in the ultrasonic detection of popliteal vein reflux. J Vasc Surg 1993;18:742-8.
3. Sarin S, Sommerville K, Farrah J, Scurr JH, Coleridge Smith PD. Duplex ultrasonography for assessment of venous valvular function of the lower limb. Br J Surg 1994;81:1591-5.
4. Lagattolla NR, Donald A, Lockhart S, Burnand KG. Retrograde flow in the deep veins of subjects with normal venous function. Br J Surg 1997;84:36-9.
5. Labropoulos N, Mansour MA, Kang SS, Gloviczki P, Baker WH. New insights into perforator vein incompetence. Eur J Vasc Endovasc Surg 1999;18:228-34.
6. Manzo R. Duplex evaluation of chronic venous disease. In: Strandness DE, ed. Duplex scanning in vascular disorders. Philadelphia, Pa: Lippincott Williams & Wilkins, 2002:368-78.
7. Foldes MS, Blackburn MC, Hogan J, Klemp K, Rutherford K, Thorpe L, et al. Standing versus supine positioning in venous reflux evaluation. J Vasc Tech 1991;15:321-4.
8. van Ramshorst B, van Bemmelen PS, Hoeneveld H, Eikelboom BC. The development of valvular incompetence after deep vein thrombosis: a follow-up study with duplex scanning. J Vasc Surg 1994;19:1059-66.
9. Anderson J, Thurin A, Thulesius O. Valvular function of peripheral veins after hyperemic dilation. J Vasc Surg 1996;23:611-5.
10. Rosfors S, Bygdeman S, Nordstrom E. Assessment of deep venous incompetence: a prospective study comparing duplex scanning with descending phlebography. Angiology 1990;41:463-8.
11. Welch HJ, Faliakou EC, McLaughlin RL, Umphrey SE, Belkin M, O'Donnell TF. Comparison of descending phlebography with quantitative photoplethysmography, air plethysmography, and duplex quantitative valve closure time in assessing deep venous reflux. J Vasc Surg 1992;16:913-20.
12. Neglen P, Raju S. A comparison between descending phlebography and duplex Doppler investigation in the evaluation of reflux in chronic venous insufficiency: a challenge to phlebography as the "gold standard." J Vasc Surg 1992;16:687-93.
13. van Bemmelen PS, Beach K, Bedford G, Strandness DE Jr. The mechanism of venous valve closure: its relationship to the velocity of reverse flow. Arch Surg 1990;125:617-9.
14. Markel A, Meissner MH, Manzo RA, Bergelin RO, Strandness DE Jr. A comparison of the cuff deflation method with Valsalva's maneuver and limb compression in detecting venous valvular reflux. Arch Surg 1994; 129:701-5.
15. Labropoulos N, Athanasios DG, Kostas D, Mansour MA, Kang SS, Nicolaides AN, et al. Where does venous reflux start? J Vasc Surg 1997;26:736-42.
16. Abu-Own A, Scurr JH, Coleridge Smith PD. Saphenous vein reflux without incompetence at the saphenofemoral junction. Br J Surg 1994; 81:1452-4.
17. Labropoulos N, Giannoukas AD, Delis K, et al. The impact of isolated lesser saphenous vein system incompetence on clinical signs and symptoms of chronic venous disease. J Vasc Surg 2000;32:954-60.
18. Stuart WP, Lee AJ, Allan PL, Ruckley CV, Bradbury AW. Most incompetent calf perforating veins are found in association with superficial venous reflux. J Vasc Surg 2001;34:774-8.

Submitted Feb 28, 2002; accepted Mar 10, 2003.